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A MATHEMATICAL PROGRAMMING APPROACH TO DETERMINE THE OPTIMUM CROPPING PATTERN: A CASE STUDY

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ABSTRACT

This study was undertaken for four medium farmers in the village Bherian, district Hisar. The crops sown by the farmers in the kharif season were cotton, guar and Jowar. The Data was collected through a pre structured schedule which includes total land holdings, season wise land allocated to crops, fallow areas, man days, tractor hours, operating capital and net returns from the farmers' enterprise. The aim of study was to plan a suitable optimum cropping pattern to get returns more than the existing net average returns of farmers using mathematical programming approach. The model thus produced, suggested different alternate plans of cropping patterns that give a higher income than, that could be obtained from the farmer's plan.

KEYWORDS: Mathematical Programming, Optimum Cropping Pattern, Medium Farmers, Income & Net Returns

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1. INTRODUCTION

Medium and small farmers are usually faced with the problem of how to allocate their limited resources cultivating different crops, so that they can maximize their income. Farmers, often, follow their instinct and experience to handle this problem.

The Economic Survey 2015-2016 regarding the crop yield comparison of India versus the World shows that there is an enormous difference in the highest yield of India compared to the world's highest yield, in almost all crops. Punjab is the highest yielding state in paddy with 3952kg/hectare (in 2012) as compared to 6661kg/hectare in China. In case of wheat, Punjab had been producing 5071 kg/hectare where in U.K. it was 7360 kg/hectare. Similarly there is a wide gap in case of other crops also. This provides ample opportunity to increase production by bringing the yield gap to the maximum extent feasible. This increase in the production will increase the income of Indian farmers of all categories. The increase in production is directly related to the available resources and their judicious use.

Farm planning problems are much more complex. Farmers not only produce different crops, but also have to choose among a variety of ways of producing them. Crop planning may involve choices about varieties, planting dates, and fertilizer and pesticide treatments. Linear Programming has been used in agriculture almost since its very inception for planning the best possible allocation of scarce resources. Hazel and Norton (1986) say, "Traditionally, farmers have relied on experience, intuition and comparisons with their neighbours to make their decisions". Instinct

and experience do not guarantee optimal results; however, farm planners can offer effective techniques, such as, linear programming (LP), to address such problems and produce optimal solutions (1986). Mohamad and Said (2011) developed an LP Crop Mix Model for a finite-time planning horizon. Majeke et al. (2013), modelled a small farm livelihood using Linear Programming Model in Zimbabwe. Results obtained from the model were compared to traditional farming methods and a difference of 44.65% was achieved with the model. Nedunchezhian and Thirunavukkarasu (2007) developed an LP model to optimize farm plans in different farming systems in Orathanadu block of the Thanjavur district in Tamil Nadu. Shukla et al. (1994), analysed the income and employment in crop, dairy and poultry enterprises. Radhakrishnan D (1962) and Raj Krishna (1963) proposed the LP technique for determining the optimal farm planning. Hassan et al. (2005) reported that farmer's profit cannot be maximized without optimum cropping patterns, which ensure efficient utilization of available resources; and therefore the use of LP makes it possible to devise a stable solution, which includes the specification of product's levels, factor and prices. Developing a prototype enterprise cropping plan in arable crop production would be useful in the extension education package for use by extension workers. This is because how the farmers are to use any developed technologies and incentives would depend on their effective and efficient utilization of their productive resources (Furton and Clark, 1982). The prototype enterprise combination expected from this study shall thus assist in answering many resource allocation problems that would enhance farm productivity.

Barker (1964) conducted a study using L.P in making farm management decisions and came to the conclusion that "L.P. can be valuable in farmer decision specified alternatives, levels of resources use and the larger the size of farm, the larger the number of alternatives. Poonia [2016] et al proposed a linear programming model to suggest optimal crop combination for rural farmers in Hisar district, Haryana. Palash and Bauer [2017] suggested the small holders, that they can improve their gross margins by improving the allocation of the available physical and non-physical resources.

In fact, marginal and small farmers really need every type of support to increase their income. But the increase in income of all type of farmers is equally important for the progress of society as a whole. The present study was undertaken with the objective of finding the optimal crop plans for medium farmers.

This paper analyses the study undertaken in the village of Bherian in the Hisar district of Haryana . The data was collected from medium farmers for the Kharif season. The crops sown by the farmers were cotton, guar and jowar. Data regarding total land holdings, season wise land allocated to crops, fallow areas, man days, tractor hours, operating capital and net returns from the farmers' enterprise were collected through a pre- structured schedule. The LP problem was solved using MS Excel 2007, a computer application software package.

2. METHODOLOGY

In this paper, the experiment was conducted for medium farmers in Bherian, Hisar. In this context, the data was collected for three crops cotton, guar and jowar during the kharif season from four farmers. The Linear Programming (LP) model was developed using the averages of the sampled data with the objective to maximize the net return at the end of the kharif season. The resource constraints considered in the study were land, man days, tractor hours and operating capital, were kept same as obtained from the farmer's sample

The decision variables of LP model were:

x_1 = acres allocated for cotton /wheat crop

x_2 = acres allocated for guar/mustard crop

x_3 = acres allocated for green fodder crop.

x_3 = acres left fallow.

The linear programming model is

Max Z = $c_1x_1+c_2x_2 + c_3x_3 +c_3x_4$

Subject to $x_1 + x_2 + x_{3+}\ x_4 \leq L$ (land constraint)

$d_1x_1+d_2x_2 + d_3x_{3+}\ d_4x_4 \leq D$ (labour constraint)

$h_1x_1+h_2x_2 + h_3x_3 + h_4x_4 \leq$ (Tractor Hours)

$r_1x_1+r_2x_2 + r_3x_3 + r_4x_4 \leq R$(Operating Capital)

Table 1: Linear Programming Matrix, the Right Hand Side (RHS) Represents the Constraints on the Resources

Resources	Cotton	Guar	Jowar	Fallow	RHS
	Per Acre				
Land allocation (acre)	1	1	1	1.65	≤ 17
Man days	42	26	36	-	≤ 568.60
Tractor hours	6	5	4	-	≤ 85.15
Operating capital (Rs)	20125	10475	8100	-	≤ 251672.50
Net returns (Rs)	9375	11325	8650	-	≤ 151215.00

The LP model is given by

Max z = 9375 x_1 + 11325 x_2 + 8650 x_3 (Objective function)

Subject to

$x_1 + x_2 + x_{3\,+}\ x_4 \leq 17$ (Crop land constraint)

42 x_1 + 26x_2+ 36 x_3 +0 $x_4 \leq 568.60$ (Human labour constraint)

6 x_1 + 5 x_2 + 4 x_{3+}0 $x_4 \leq 887$ (Tractor labour constraint)

20125 x_1 + 10475 x_2 + 8100 $x_3 \leq 251672.50$ (Operating capital constraint)

& $x_1, x_2, x_3\ \ x_4 \geq 0$

3. RESULTS AND DISCUSSIONS

The average resources available as depicted in Table1, are 17 acres of land, 568.6 man days, 85.15 tractor hours and Rs. 2,51,672.50 of operating capital in the kharif season. The aim of study was to plan a suitable cropping pattern to get more returns than the existing net average returns of farmers which was Rs. 1, 51,215.

Before the optimization model was constructed, the farmer's existing plan was to allocate 9.75 ha for cotton, 4.25 Guar, 1.35 ha for Jowar and 1.65 ha was to be kept as fallow. The prime importance is whether this crop enterprise production combination is optimal? Does it yield maximum net returns? The resource constraints considered in this study are land, labour, tractor hours and operating capital.

The solution as in table 2, shows that the strategies for this land as specified in the model are to produce Gaur in 17 acres and no cotton or Jowar. LP also suggests that no area should be kept fallow. The net return therefore is Rs. 2, 66,122.50.

Table 2: Optimum Cropping Pattern Suggested by LP Model

	Cotton	Guar	Jowar	Fallow
Land	0	17	0	0
Net return (Rs)	266122.50			

The cropping pattern suggested by LP model showed that returns can be raised up to 76% by allocating total land to Guar crop by optimal use of all available resources. However it was not practically applicable due to uncertainty of market demand and risk factors associated with single crop along with the other basic requirements of farming system. So, alternate plans were considered and LP models were developed, by putting the constraint of maximum/ minimum requirements of land allocation under different crops.

A minimum of one acre for jowar (fodder crop) and 1.65 acre were reserved as fallow (Table 3). Remaining land was allotted (14.35 acre), with minimum land allocation restriction for cotton, being a cash crop and maximum land allocation for guar that gave maximum net returns. The minimum acreage of 4.5 and 5, maximum of 8 and 8.5 acres for guar and cotton respectively were considered for alternate plans.

Table 3: Cropping Pattern with Constraints on Land Allocation, for Alternate Plan

Alternate Plans	Constraints on Land Allocation (Acre)			
	Cotton (min)*	Guar (max)**	Jowar (min)	Fallow (min)
Farmer's plan (**Control**)	9.75	4.25	1.35	1.65
Plan-1	8.5	4.5	1	1.65
Plan-2	8.5	8	1	1.65
Plan-3	6	7	1	1.65
Plan-4	5	8	1	1.65

*Min. - minimum, **Max.-maximum

The net returns obtained by LP model for alternate plan 2, plan3 and plan 4 are quite noticeable (Table 4). These plans give alternate options of cropping pattern to a farmer's enterprise using the same resources that had been used in farmer's plan. The farmer can be suggested to follow the alternate plan 2, 3 or 4 because this is a middle path approach with net returns of 9.66%, 18.48% and 26.15% respectively. All these plans address the issue of uncertainty of market demand and risk factors associated with crops along with the other basic requirements of farming system.

Taking into consideration the efficient and economic utilization, without any restriction on land allocation to various crops during Kharif season, using available resources to the maximum extent possible to yield the highest possible return was 76%. However with land allocation constraints to various crops, net returns ranging from 9.66% to 26.15% can be achieved from three suggested alternate plans along with consideration of cropping patterns and risk factors *i.e.*, productivity and price in market, associated with various crops.

Table 4: Net Returns from farmer's Alternate Plans Cropping Pattern for Kharif Season

Plan	Cropping Pattern (Land Allocation in Percent)				Net Returns %
	Cotton	Guar	Jowar	Fallow	
Farmer's plan	57.35	25.00	7.94	9.71	0
LP model (without constraints)	0	100.00	0	0	76
Plan 1	56.62	26.47	7.21	9.71	0.98
Plan 2	50.00	34.41	5.88	9.71	9.66
Plan 3	43.24	41.18	5.88	9.71	18.48
Plan 4	37.35	47.06	5.88	9.71	26.15

Using minimum and maximum requirement constraints and applying the LP model, the cropping pattern suggested by LP model for alternate plan 1 shows that returns can be raised up to 0.98% by allocating 9.63 acres to cotton and 4.50 to guar crop by optimal use of almost all available resources (0.98%).

Alternate plan 2 suggested that combination of 8.50 acre cotton, 5.85 acre guar, 1 acre jowar and 1.65 fallows raised the income up to 9.66%.

Alternate plan 3 suggested that combination of 6.35 acre cotton, 8.0 acre guar, 1 acre jowar and 1.65 fallows raised the income up to 26.15%.

The net returns obtained by LP model for alternate plan1, alternate plan 2 and alternate plan 3 are quite noticeable (Table 4). These plans give alternate options of cropping pattern to a farmer enterprise using the same resources that he had used in his plan. Increase in guar area is almost directly proportional to increase in net income.

4. CONCLUSIONS

The efficient and economic utilization of available resources to the extent possible, without any restriction on land allocation to various crops during the Kharif season, the highest possible return was 76%. However with land allocation constraints to various crops, a net returns ranging from 9.66% to 26.15% can be achieved from three suggested alternate plans along with consideration of cropping pattern and risk factors *i.e.*, productivity and price in market, associated with various crops.

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